Thermal Inertia Mapping to Determine Location of Lunar Lava Tubes

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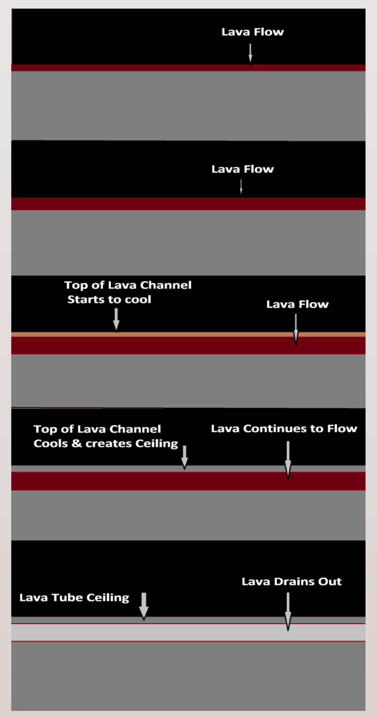
Introduction

Purpose:

Our purpose is to design an alternative method of locating lunar lava tubes for possible use in habitation. We hypothesized that through using thermal inertia mapping as opposed to visual imagery, we could locate intact lava tube cavities because lava tubes have a higher thermal inertia than their surrounding environments.

Lava Tubes: Formation & Structure:



Lava tubes originated from ancient volcanic lava flows. As lava flows, the stream of lava slowly carves into the surface, eventually sinking deeper into the surrounding material. Over time, the top of the lava cools and creates a ceiling. After the ceiling forms, the lava may continue to flow. The lava then drains out, leaving a hollowed lava tube.

Potential Usage:

Lunar lava tubes are being considered as possible shelters that would provide a hospitable environment for human habitation. Lava tubes remove the need for massive digging or burrowing. They also have potential to provide shielding from cosmic and UV radiation, meteorite impacts, and extreme temperatures. On the surface of the Moon, temperatures are extreme because there is no atmosphere to stabilize the thermal energy difference between day and night. However, the temperature inside the lava tubes is more stable, at a nearly constant 257 K, which better fits human living conditions.

Identification:

Cassandra Coombs has attempted to identify lunar lava tubes using visual images. Of the 15 lava tube candidates that Coombs identified, most were located in four primary mare locations, which are sites of ancient volcanic activity. Coombs concluded that uncollapsed segments between two or more collapsed segments along the trend of a sinuous rille may indicate the presence of lava tubes.

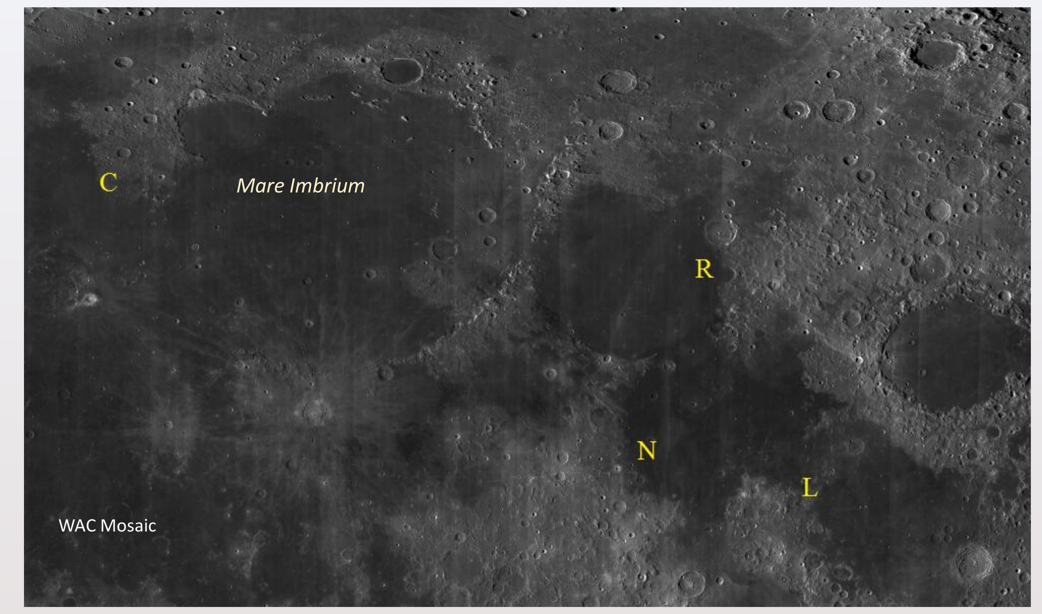
However, because of the difficulty in finding surface expression for intact lava tubes, which could be masked by secondary lava flows or impact ejecta, thermal inertia mapping, alongside of visible imaging, has been used in an attempt to identify lava tubes. (Meyer)

Thermal Inertia Data

Thermal Inertia:

Thermal inertia is the tendency for a material to conduct and store heat. The heat is stored during daytime and let off during the nighttime and thermal inertia is a means of measuring this heat transfer. For the purposes of this hypothesis, we used a pseudo thermal inertia which is given by the difference between daytime and nighttime temperatures. The greater the difference, the less thermal inertia and vice versa.

A large thermal inertia chiefly indicates small particulate size, or the presence of a thermally insulated lava tube. In the case of a lava tube, the thermal inertia would have to be in the form of a sinuous line.



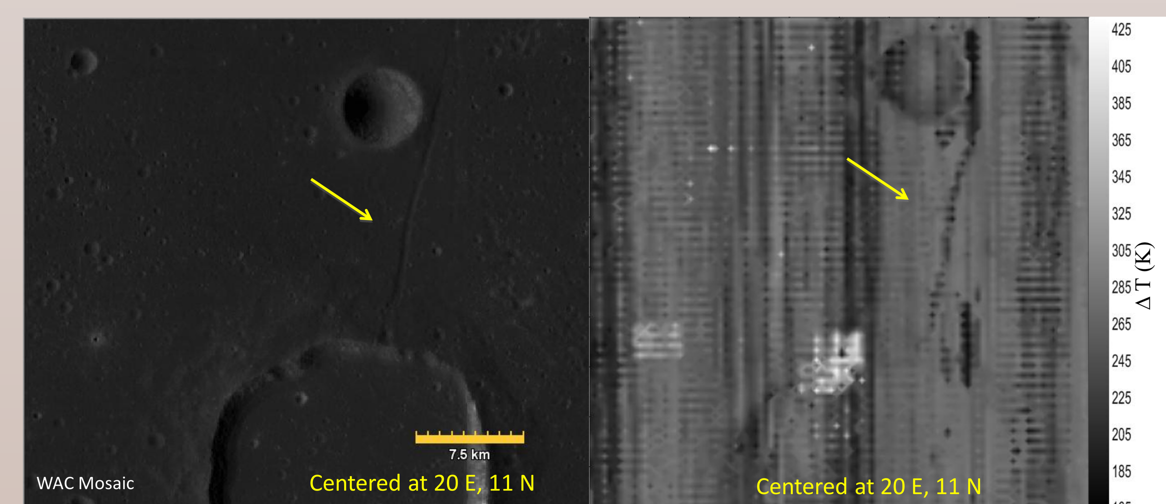
Data Collection Process:

We identified the location window of each lava tube using JMARS and then downloaded the temperature data for that window from the Lunar Orbital Data Explorer website. We obtained files containing daytime and nighttime temperatures and then separated the data into two files, one daytime (275 to 400 K), and one nighttime (75 to 125 K). We then used Surfer to make two maps, day temperatures and night temperatures, and then subtracted the nighttime grid from the daytime grid to create our thermal inertia map.

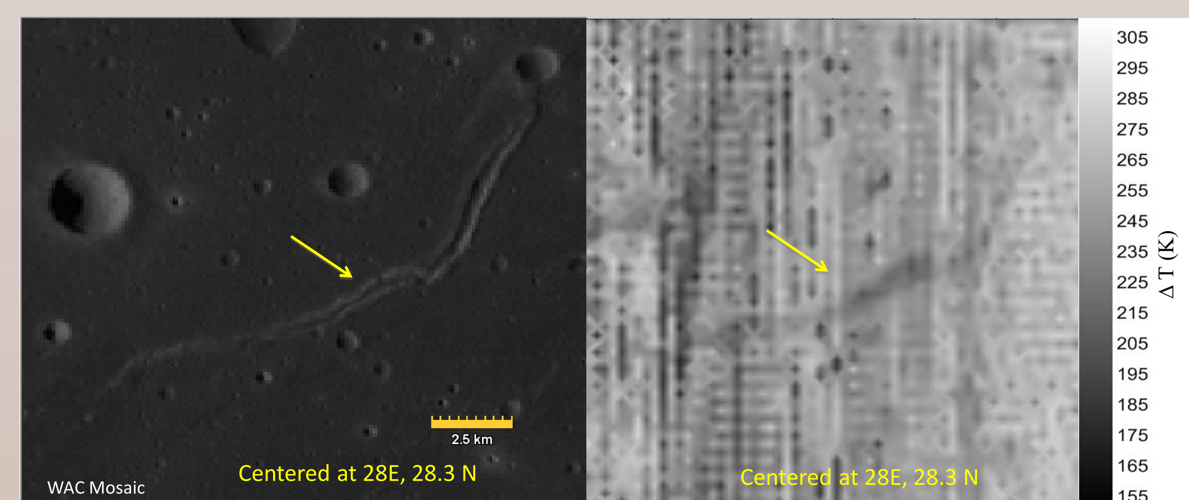
We used thermal inertia mapping in our research to identify lunar lava tubes. Lava tubes have a higher thermal inertia and lower diurnal temperature difference than the surface of the Moon. Therefore, by locating areas with the least change in temperature between day and night we are able to approximate locations of lava tubes and compare that to visual images from the Lunar Reconnaissance Orbiter Camera. We focused our research on four of the lava tubes labeled by Coombs – lava tubes N, R, L and C.

Comparison of Visible & Thermal Inertia Maps :

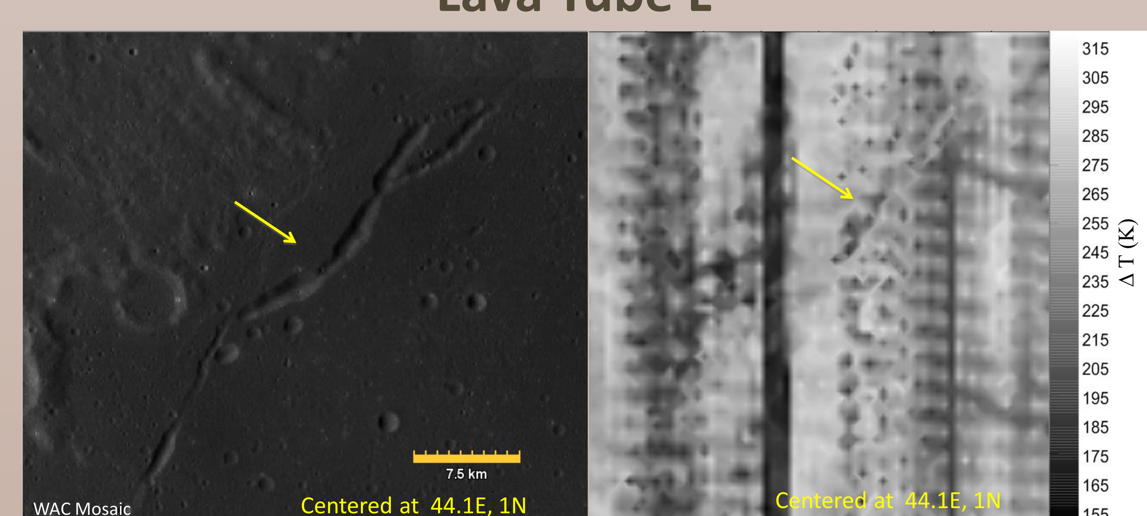
Lava Tube N



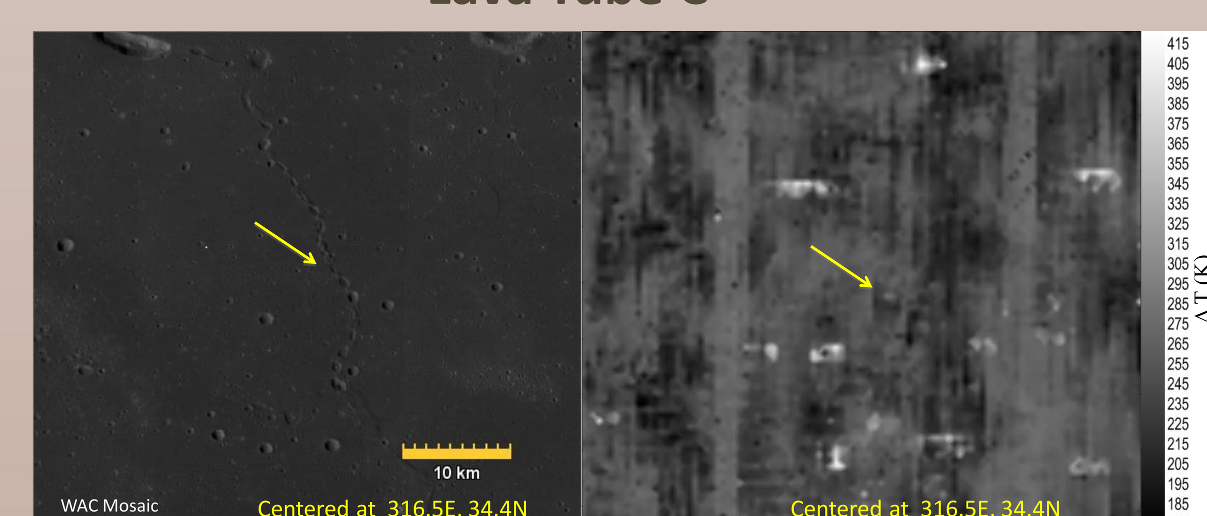
Lava Tube R



Lava Tube L



Lava Tube C



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References:Coombs, C. R. & Hawke, B. R., (1992). A search for intact lava tubes on the Moon: Possible lunar base habitats. In NASA. Johnson Space Center, The Second Conference on Lunar Bases and Space Activities of the 21st Century, Volume 1 p 219-229 (SEE N93-17414 05-91) [1]

Meyer, Jonathan A. (2012). New Methods for the Discovery and Characterization of Lunar Lava Tubes Using Lunar Reconnaissance Orbiter Data. The University of Texas at El Paso. [2]

LROC Data http://ode.rsl.wustl.edu/moon/indextools.aspx?displaypage=lrodiviner

Thermal Inertia: http://www.boulder.swri.edu/inertia/

Christensen, P.R.; Engle, E.; Anwar, S.; Dickenshied, S.; Noss, D.; Gorelick, N.; Weiss-Malik, M.; *JMARS - A Planetary GIS*, **http://adsabs.harvard.edu/abs/2009AGUFMIN22A..06C**

Analysis

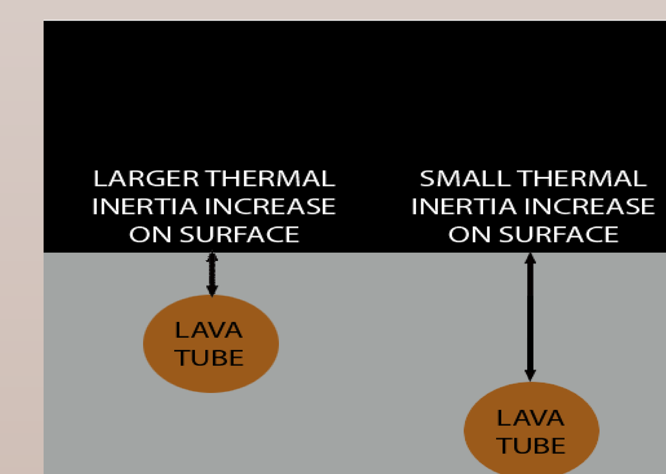
Vertical Lines:

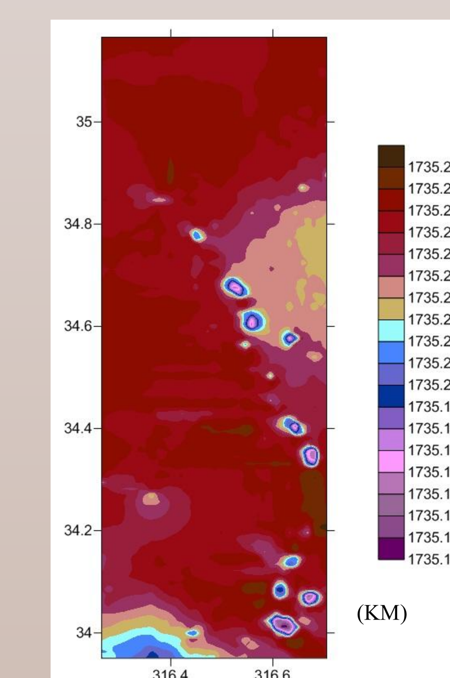
The vertical lines that appear in the thermal images distort the appearance of possible lava tubes. These lines may be a result of the nature of the orbiter's vertical path. If the orbiter passed over an area early in the day (~300K) and early at night (~125K), we would see a smaller temperature difference, resulting in a darker vertical line compared to if the orbiter passed over the area later in the day (~400K) and later in the night (~75K).

Results:

We observed similarities between our thermal inertia maps and the images obtained from the LROC. For lava tubes N, R, and L it is very clear that there are lava tubes that match up almost exactly in their sinuosity and the proximity to craters. Based on these similarities, it is very likely that our thermal maps are confirming the existence of a lava tube as suggested by LROC images. However, in the case of lava tube C, our thermal inertia map did not show large sections of the lava tube seen in the visual image.

In an effort to explain the discrepancies found between the visual and thermal image of lava tube C, we looked at three possible reasons. Initially we thought that the data resolution may have been inadequate for identifying small features such as lava tube C but we calculated that data resolution was sufficient. The second possibility we considered was related to the depth of the lava tube. Lava tubes deeper under the lunar surface would have a smaller effect on surface thermal inertia. We also created elevation maps from LOLA data to see if sections of the lava tube were collapsed and compared them to the thermal inertia maps. We found no correlation between the two.





Summary:

Our goal was to find a method for using thermal inertia to identify intact lunar lava tubes, which have great promise for human habitation. We looked at four potential lava tubes that had been previously identified by Cassandra Coombs using visible imaging. Of the four, three were clearly identified in the thermal inertia mapping. A thermal inertia difference may be a result of the properties of the material(s) at the target location and not necessarily a lava tube; however, based on the visible map, we conclude that the method of thermal inertia mapping has strong potential to identify intact lunar lava tubes.

As an extension, we hope to identify undiscovered lava tubes on the perimeter of the mare region using thermal inertia mapping. The mare perimeter is our target area because we have found it to be the main location of known lava tubes.